Liquid crystal biosensing of microorganisms

José M. Otón, Eva Otón, Xabier Quintana, Morten A. Geday

Links between liquid crystals and living systems are well established since the early origins of the field. However, LC applications to biological issues have been scarce until recently. Detection of harmful microorganisms with simple, portable tests based on lyotropic chromonic liquid crystals (LCLC) was proposed a decade ago, as a counter measurement for bioterrorist attacks [1]. The same group demonstrated recently compatibility of living systems (e.g., swimming bacteria) with LCs and mutual interactions between the microorganisms and the LC medium [2].

The detection is ultimately based on the disorder induced by the microparticles (whether living or not) on the otherwise ordered LCLC. Selective detection of a given specimen usually requires a procedure in parallel, namely an additional surface activation to attach the microparticle to one of the inner surfaces of the cell, where it eventually may interact with the LCLC. When detecting microorganisms or biological macromolecules, the activation is customarily performed with specific antibodies attached to the surface.

The key point for LC detection of microparticles is amplification [3]. The dimensions of microorganisms, let alone macromolecules, are often in the range of a few μm or below this, i.e. close to or below the working range of regular optical microscopes. It has been observed, however, that the area where the microparticle modifies the LC order is significantly larger, making the disordered areas easily detectable as bright points between crossed polarizers.

Our aim has been the development of a point-of-care, affordable, portable sensing equipment for detection of specific harmful microorganisms like bacteria or unicellular algae in healthcare or food chain environments. Our approach has been twofold: on the one hand, we have tested alternative surface activations, other than antibodies, for selective detection of some pathogens (*Legionella*, *Salmonella*, *Meningococcus*, *Listeria*…); on the other hand, detection of microorganisms trapped by the activated surface has been tried using three different techniques: total internal reflection, surface acoustic waves, and lyotropic chromonic liquid crystals.

Surface activation using aptamers rather than antibodies has been tested. Aptamers are short (80-120) single-stranded DNA chains that can be made highly specific to a certain microorganism or protein. Detection with different techniques has been positive in all cases, but ranges and conditions vary widely. Detection with LCLCs has demonstrated to be the simplest one, requiring just a holder for the test cell.

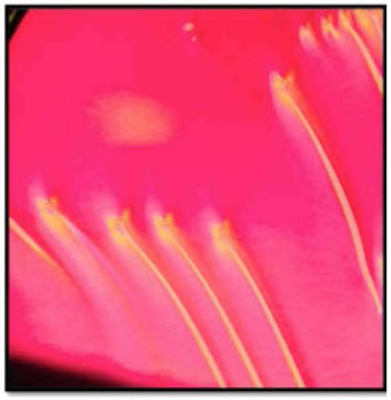

Figure 1. Amplification of microparticle detection as seen during liquid crystal flow.

The presence of pathogens with LCLCs is perceived by the naked eye, being not necessary any supplemental optical system. This has been made possible by working on the optical amplification mechanism. A new procedure [4] has been developed to increase significantly the amplification of the optical signal. It is based on a dynamic smearing effect that generates large trailing signals (Figure 1) while the liquid crystal is flowing (i.e., filling up the cell) in the presence of trapped targets. Once the LC flow is stopped, the effect persists for several minutes until it fades out. While the previously described static amplification is about 5× to 15×, the new dynamic effect produces amplifications 100× to 300×, making it possible to observe the microparticles with no optical instruments.

[1] S.V. Shiyanovskii, O.D. Lavrentovich, T. Schneider, T. Ishikawa, I.I. Smalyukh, C.J. Woolverton, G.D. Niehaus, K.J. Doane; "Lyotropic Chromonic Liquid Crystals for Biological Sensing Applications" Mol. Cryst. Liq. Cryst. **434**, 259-270 (2005).

[2] S. Zhou, A. Sokolov, O.D. Lavrentovich, I.S. Aranson; "Living liquid crystals" **111** (4) 1265–1270 (2014) doi: 10.1073/pnas.1321926111.

[3] V.K. Gupta, J.J. Skaife, T.B. Dubrovsky, N.L. Abbott "Optical amplification of ligand-receptor binding using liquid crystals" Science **279**, 5359-5362 (1998).

[4] M.A. Geday, E. Otón, J.M. Escolano, J.M. Otón, X. Quintana "Method for amplification of target detection in an aligned matrix of liquid crystal" Patent# ES 2 499 790 (2014).